The Game of Heritage Destruction

Josep Grau-Bové

April 23, 2020

Contents

1 Rules

1.1 Rules in brief

Two or more teams (or single players) compete to destroy as much heritage as possible.

This is an educational game. The experience is enjoyed to the fullest if one of the players is familiar with preventive conservation principles and can teach the other players. It is also a debating game, where players must persuade each other using conservation knowledge.

The rules are simple:

1. Each team gets 5 cards
2. Team A selects an object and shows it.
3. All teams including Team A look for the agent of deterioration (red side) that will be more damaging to that object. The selection of damage needs to be reasoned. Teams can use their conservation knowledge and read conservation guidelines. A good reasoning should describe both a plausible environment and the value of the object.
4. Teams negotiate. This turn can be played with a moderator. The teams agree who has the more damaging and logical (or more fun) set of cards.
5. The winning team keeps the destroyed object plus all cards played by the other teams.
6. After 5 turns, or when cards run out, the team with most cards wins.

1.2 Inflicting damage

Only 1 card can be selected unless one of the cards is a modifier. There are two modifier cards. One causes a fluctuation of whatever agent is linked with it. The other one causes a spike, a sharp increase or decline.

It is also possible to use more than one card if players come up with a combination of cards that makes sense in the real world. For example, it wouldn't be necessarily logical to mix pests with an earthquake and high temperatures, as there are no well known events that combine these problems. It would just be a very bad day. However, players could come up with a card combination like the following one:

This combination might mean "rain followed by a sharp decrease (negative peak) of temperature, which will cause freeze-thaw damage". It is a realistic and very damaging scenario. But the team or player who plays this hand is also taking a risk. If the other players are not persuaded, and find this scenario unlikely, the player will loose three the cards to the winner of the round. However, if they construct a plausible scneario, the use of multiple cards might prove more persuasive than a single card.

1.3 Using "value" in your story

The best proposed destruction methods consider the value of the objects being destroyed. For example, let us consider that we want to destroy the Crown Jewels:

Some players may contend that the Koh-i-Noor diamond is the more valuable object on the crown. Since a diamond is very difficult to destroy, the only possible mechanisms to harm it would be theft or perhaps wear and tear. However, theft is unlikely and the diamond is not used frequently. Other players could argue that what gives the Crown Jewels great value is their gloss and pristine appearance. Therefore, coarse or fine dust could reduce value very easily. Other players could even defend that the authenticity of the materials is central to the value of the crown. Perhaps the materials contain traces of DNA of the queens that have worn it. Perhaps the materials have been chosen by the monarchs themselves. Therefore, pests eating the textile elements would be very destructive, even if textiles could eventually be replaced.

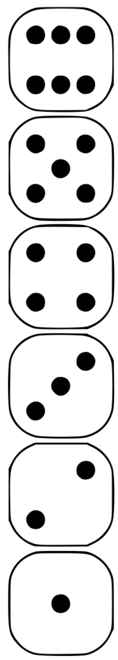
To sum up: Finding what is more damaging is a question of "value" as much as "deterioration".

1.4 Using the dice

The game can be played with or without dice. Players can be very quantitative, and decide who wins by looking at the damage indicated by the dice. Or they can place more emphasis on the quality of the hypothesis being put forward. In both cases, it helps to have clear numerical values of the agents of deterioration in play. The dice are used in two ways:

- To decide the magnitude of an agent of deterioration, using the table provided below.
- To determine whether an event occurs. Some agents of deterioration are 'risks' with a probability. To reflect this reality, two dice should be rolled obtaining a number higher than the number on the card.

The value of the dice can be translated to the magnitude of agents of deterioration using the following table:



RH	T	ppb	lux	Dust
50/50	20	0.1	10	0.1%
60/40	25	1	100	1%
70/30	30	10	1K	5%
80/20	40	100	10K	25%
90/10	50	1K	0.1M	50%
100/0	80	10K	1M	100%

Of course, not all agents affect all materials in the same way. Each agent is harmful to some materials and not to others. The relationship between agents and deterioration is a complex area, still under research. It is not easy to generalise. However, players looking for quick answers can use the following tables. They have been adapted from current guidelines for heritage institutions, such as PAS198:2012.

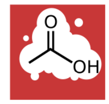
The damaging effects of light are quite well researched. However, they require knowledge of which materials are of "low" or "high" sensitivity. Players will have to use their common sense, and persuade others that their hypothesis is valid.

Light damage (years to visible change)

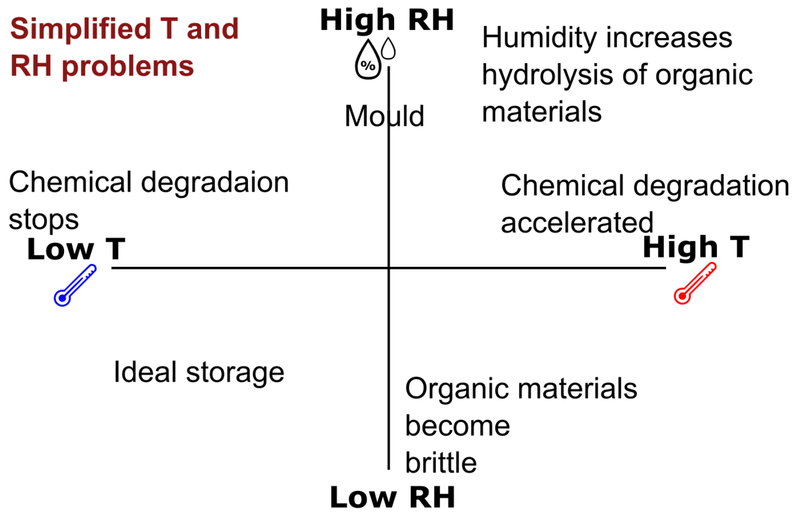
illuminance	low sensitivity materials	high sensitivity materials
50 (barely lit)	7000	20
150	2000	7
500 (office)	700	2
5000 (window)	70	2 months
30000 (dailyight)	10	2 weeks

In order to estimate acceptable pollutant concentrations for storage of materials, researchers have defined ”thresholds” of concentration. The idea is that under these thresholds, damage is very unlikely. The following table summarises some of these thresholds:

Threshold concentrations (ppb)

	NO_2	SO_2	O_3	H_2S	
Ceramics					1000
Fossils					1000
Shells					1000
Lead				10	100
Copper					1000
Silver				10	
Lead pigments				10	1000
Paper	10	1	10		100
Leather	100	10			1000

A PhD thesis could be written on the topic of Temperature and Humidity alone. The following plot provides a very quick reference to the main processes. In short, when things are wet and hot, degradation is faster. When things are dry, brittleness may be a problem.

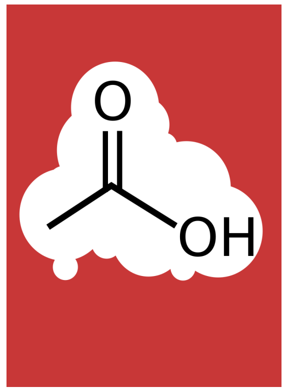


2 Agents of deterioration

What is more damaging to paper, 80% RH or 10 ppb of NO_2? Many such questions don't have easy answers. The Game of Heritage Destruction will rarely result in clear-cut decisions. Rather, players will have to weight the evidence and decide who has presented the most convincing and likely case (or the more hilarious one).

This section provides a summary of the effects of the main agents of deterioration in order to inform the debates between players. This content has been extracted and abridged from the descriptions provided by the Canadian Conservation Institute: `https://www.canada.ca/en/conservation-institute/services/agents-deterioration.html`

2.1 Acetic acid

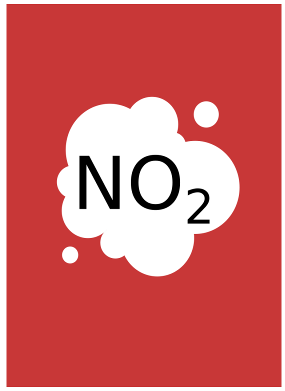


This carboxylic acid (CH3COOH) is mainly generated indoors when inappropriate products are used, and may cause problems in airtight enclosures. Typically, an enclosure constructed using poorly chosen wood and paints will cause problems. Lead is the most sensitive material to acetic acid and it is often found corroded where acidic woods or inadequate paints are chosen to build display or storage cabinets.

2.2 Hydrogen sulfide

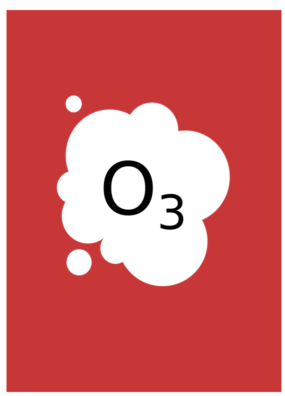
Hydrogen sulfide (H2S), a reduced-sulfur gas with a characteristic ”rotten egg” odour, is a key pollutant due to its great ability to tarnish silver and copper within a very short time, even outside of urban areas. The darkening of lead white pigment in paintings is also caused by the presence of reduced-sulfur gases. The main man-made sources of hydrogen sulfide are the pulp-and-paper and petroleum industries. Outside the urban environment, hydrogen sulfide is emitted by oceans, volcanic and geothermal activities, marshes, and vegetation. Inside buildings, staff and visitors are often the major source of hydrogen sulfide.

2.3 Nitrogen dioxide



The most common compound of the nitrogen oxide group (NOX), nitrogen dioxide (NO2) is responsible for the reddish brown colour above cities, especially during periods of photochemical smog. NO2 is formed rapidly in the atmosphere by the action of ozone on nitric oxide (NO), which is the major nitrogen oxide emitted by combustion in vehicles (about 50% of emissions), power plants, and industrial activities. In the atmosphere, a fraction of nitrogen dioxide can be further oxidized to its acid form: nitric acid (HNO3). Both nitric acid and nitrogen dioxide cause artists' colorants to fade and can contribute to the degradation of paper and vegetable-tanned leather. It is also believed that the nitrogen oxide absorbed by objects becomes oxidized to nitric acid, the latter being responsible for most of the ensuing deterioration.

2.4 Ozone

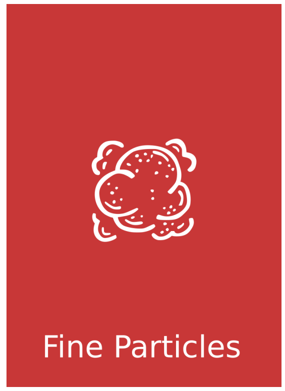


Ozone (O3) is a strong oxidant that is normally present in the stratosphere and protects us against intense, harmful ultraviolet radiation. At ground level, it is formed during photochemical smog. Photochemical smog is the result of multiple chemical reactions between nitrogen oxides and hydrocarbons, and their oxygenated derivatives in the presence of sunlight. Inside buildings, the main sources of ozone are electrostatic precipitators in the heating, ventilation, and air-conditioning (HVAC) system, electronic air cleaners (ozone generators), and photocopiers. Ozone has the capacity to attack materials by breaking apart any double bonds between carbon atoms. The degradation of vulcanized natural rubbers under stress and the fading of artists' colorants are the most studied phenomena.

2.5 Sulfur dioxide

In the United States and in Europe, power plants based on coal and oil combustion are the major sources of sulfur dioxide (SO2), followed by industrial processes and transportation. Only small quantities of sulfur dioxide come from gasoline-fuelled motor vehicle exhaust. In the UK, industrial activity, specifically metal smelting, is the main source of sulfur dioxide. Inside enclosures materials such as proteinaceous substances, sulfur-vulcanized rubbers, oxidizing sulfides in geological specimens, and some dyes are sources of sulfur compounds. Sulfur dioxide causes corrosion of copper, fading of some artists' colorants and weakening of vegetable-tanned leathers. Both sulfur dioxide and nitrogen dioxide have been largely associated with the acidification of papers where acid rain and urban pollution are an acute problem.

2.6 Fine particles



It is common to characterize particulate matter (dust) in terms of aerodynamic diameter. The aerodynamic diameter is important, because it determines its behaviour and control. For the control of pollutants, the fine particle (PM2.5: suspended particle matter having an aerodynamic diameter equal to or less than 2.5 microns) and the coarse particle (PM10: aerodynamic diameter between 2.5 and 10 microns) are commonly used as indicators. Due to the small size of PM2.5, it is the most challenging particle size to control. Sulphate and nitrate compounds, organic carbon, crustal materials, and salts are the major harmful outdoor compounds forming fine particulate matter. Fine particles are particularly damaging, because they discolour or soil surfaces.

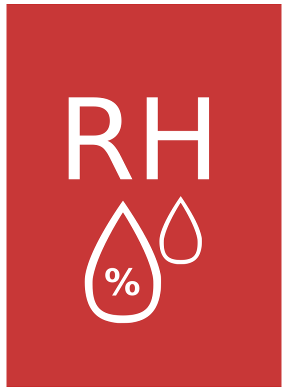
Soiling changes the visual appearance of objects. The more fragile, porous, or altered the surfaces, the more difficult they are to clean. Object cleaning is a delicate process that requires trained conservators. The deposit of hygroscopic, oily, or metallic particles on a surface can initiate or accelerate deterioration, as well as the formation of harmful compounds such as acids. With the exception of particles generated by cooking activities in a museum's cafeteria or the burning of combustibles (candles and lamps), most indoor-generated particles are composed of soil, and fibres from carpet and cloth. Fibres are not generally considered to have direct adverse effects on collections, except to magnetic media such as audio and video tapes, where abrasive dusts are an issue during handling and playing. Dust accumulation can also provide an attractive foraging place for insects, and can initiate mould. From a wider viewpoint, another adverse consequence is the impact of the perception by visitors, including potential donors, that there is a basic lack of care for the collection.

2.7 Light

Given the three distinct bands of radiation — light, ultraviolet, and infrared — one can make useful generalizations about the types of deterioration they cause in museums:

- Light fades (or "bleaches" colours). Those colours that fade can disappear within as little as a few hours of direct sunshine, or just a few years at low museum lighting (e.g. some felt tip pen inks, some colour photographs). Those which do not fade may last centuries in direct sunshine (e.g. ceramics, Minoan frescoes). All coloured objects fall somewhere between these two extremes.
- Light causes yellowing, chalking, weakening, and/or disintegration of materials. Chalking of paint media is often mistaken for pigment fading.
- Light heats the surface of objects, and thus becomes a form of incorrect temperature (too high), with all the damage possibilities outlined in the section on Incorrect temperature.
- Light (especially violet) can cause some of the disintegration and yellowing, but only in a few materials, and only very slowly in comparison to UV.

2.8 Humidity - RH



2.9 Damp (over 75%)

Damp has been understood since ancient times. It remains a constant battle, especially in the historic buildings that so often house museums. Damp causes several types of deterioration – mould, rapid corrosion, and extreme forms of mechanical damage. Although the practical boundary for damp is given as 75% , the deterioration rates all climb rapidly with increasing RH, so any reduction below 100% is beneficial. Damp causes mould, which disintegrates or discolours skin, leather, textiles, paper, basketry, and occasionally wood, paint, and glass.

2.9.1 Above or below a specific critical value

Some minerals deliquesce above a certain RH, i.e., they form a salt solution by absorbing moisture from the air. For example, common table salt, sodium chloride (NaCl) deliquesces at 75% , and is widely used to melt ice on roads.

In archaeological iron and bronze, a complex sequence of critical RH values, each due to a specific compound in the chain of corrosion, determines the rate of corrosion. In general for metals, the lower the RH the better, above 75% RH all corrosion speeds up a lot.

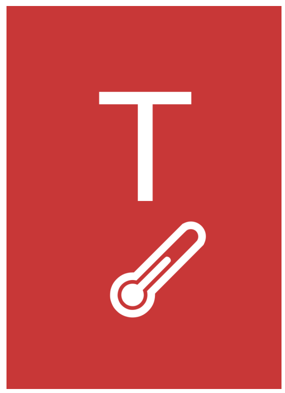
Unstable glass ”sweat” when the RH is above a critical level (55%) because fluxing compounds in the glass deliquesce, on the other hand they ”crizzle” when the is below the critical level (40%) that causes dehydration of other compounds in the glass. The gap between these two critical forms the safe range for these unstable glasses.

A small fraction of minerals, such as hydrates and pyrites have specific critical above or below which they can crumble and or weep.

2.9.2 Above 0% (when any water vapour is incorrect)

This may seem an odd definition for an incorrect RH, but it applies to all those archival materials such as acidic paper, magnetic tape, acetate and nitrate films, that decay chemically within a few decades – becoming weak, yellow, and brittle, or in some cases sticky. The chemical reaction behind this decay – acid hydrolysis – requires moisture, so the presence of any water vapour, any RH above 0%, permits the reaction to proceed. The rule of thumb is that the rate of decay can be cut by more than half each time the RH is halved.

2.10 Temperature



Temperature, unlike fire, water, pests, etc., cannot be considered an agent of deterioration — we cannot speak of avoiding ”temperature.” From a collection risk and deterioration perspective, we must speak of incorrect temperatures.

- Temperature too high. This category can be subdivided into chemical, physical, and biological phenomena. The most important one for museums and archives is chemical: normal room temperatures are much too high for the long-term preservation of unstable human made materials, especially those carrying images, sound, and text. In fact, for most museums, only these archive collections require any thought about incorrect temperature.

- Temperature too low. Overall, low temperature is beneficial to collections, but polymeric materials, such as paints, become more brittle and fragile. Fortunately, careful handling mitigates most of the risk.

2.11 Fluctuations

2.12 Fluctuations of RH

Finally we come to the type of incorrect RH that has concerned museums more than any other – RH fluctuations. Although the physical phenomena that underlie damage from RH fluctuation are analogous to those discussed under fluctuations in the section on Incorrect temperature, the collections that are vulnerable are not at all the same. A change in causes the moisture content of organic materials such as wood, paper, leather, photographs, negatives, plastics, paints, glues, etc. to change, which in turn causes their size to change. If the material is free to expand and contract as RH goes up and down, then there is no problem, but if the material is constrained by other components of the object, or simply by its own inner bulk during a rapid fluctuation, then expanding parts will be crushed, and shrinking parts may fracture.

2.13 Fluctuations of T

The mechanism underlying the damage is the expansion of materials as their temperature climbs, and the converse, the shrinkage as it falls. There are two situations that lead to damage: when the components of a complex assembly have different coefficients of expansion, and when an object is subjected to a fluctuation more rapid than its ability to respond evenly. Repetitive stresses can give rise to fatigue cracking. Beginning with the "single cycle stress" that causes fracture, engineering data from many materials shows that at about one quarter of this stress for brittle materials (glass, ceramics, old oil paint) and one half of this stress for tough materials (wood, paper, leather), fatigue cracking will occur after about a million cycles. By about one eighth of this stress, fluctuations will be tolerated indefinitely, but because it will take 3,000 years to reach a million daily cycles and because most objects cannot respond fully to cycles faster than this, then we can take the million cycle/one quarter stress combination as a very cautious extrapolation of how much to worry about multiple fluctuations.

3 Image credits

All images are either in the public domain or shared under creative commons licenses that allow reproduction including for commercial purposes. Sources and authors are listed in all cases, even if not requested by the license. Usage does not imply endorsement by the licensor.

```
Stonehenge image by Heinz Ebner, Pixabay
Crown by AlinavdMeulen, Wikimedia
Space invaders by BagoGames, flickr
Mary rose by Geni, Wikimedia
Cycladic figurine by Walters Museum, Wikimedia
Tudor Chimeneys by Elliott Brown, flickr
Hobbit Hole by Tom Hall, flickr
Opened old book, Pexels
Terracotta warriors by DEZALN, Pixabay
Rietveld Chair by User:Ellywa, Wikimedia
Chinese Screen by Daderot, Wikimedia
Magna Carta by J.delanoy, Wikimedia
Gilded clock by Daderot, Wikimedia
Image by ErikaWittlieb from Pixabay
Hadrian statue by Carole Raddato, flickr
Leshan Buddha by Ariel Steiner, Wikimedia
Cellini's Salt Cellar by Dr. Alexey Yakovlev, flickr
Bernini's Apollo and Daphne by Architas, Wikimedia
Gun by Rama by Wikimedia
Crucifix by Ron Sterling, Wikimedia
Stained glass by Poliphilo, Wikimedia
Old Man by Rembrandt, Getty, Wikimedia
Manneken Pis by Myrabella, Wikimedia
Stereograph by Underwood & Underwood, Wikimedia
Bronze Head by Jastrow, Wikimedia
Laboutins by Arroser, Wikimedia
Stradivarius by Scott Edmunds, flickr
Leonardo Cartoon by National Gallery, Wikimedia
Panton Chair by Sailko, Wikimedia
Roman Coins by The Portable Antiquities Scheme (PAS), Wikimedia
Butterfly collection by Mike Beauregard, Wikimedia
18c Dress by  Los Angeles County Museum of Art, Wikimedia
Cannon ball by The Portable Antiquities Scheme (PAS), Wikimedia
Lacquer vases by Adilnor Collection, Wikimedia
Acetate film by Bart by Wikimedia
Pyrammids by Ricardo Liberato, Wikimedia
Shell by Anthony Poynton by publicdomainpictures.net
Lego figure by 2Technology, pixbay
```

Tapestry by Daderot, Wikimedia
Oil Painting by Roman Michalowski, Wikimedia
Cartonnage by Walters Art Museum, Wikimedia
Roman Glass by Vassil, Wikimedia
Illuminated Parchment by Metropolitan Museum of Art, Wikimedia
Hands in a cave by Mariano, Wikimedia
Pompeii Fresco by The Yorck Project, Wikimedia
Lead soliders by Minnesota Historical Society, Wikimedia
Dolly the sheep by neverbutterfly, Wikimedia
Bentham Auto-Icon by Marit & Toomas Hinnosaar, flickr
Banksy by FaceMePLS, flickr
Golden Ring by Walters Art Museum, Wikimedia
Timber frame house by Roland Geider (Ogre), Wikimedia
Lewis Chessmen by National Museum of Scotland, Wikimedia
Sue by Zissoudisctrucker, Wikimedia
Lamb of God by Web Gallery of Art, Wikimedia